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AUTHOR	Boshuizen, Henny P. A.; And Others
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ABSTRACT

The cognitive processes that underlie a medical student's improved competence during the clerkship (clinical experience) portion of medical education were studied for high- and low-achieving medical students in the Netherlands. Nine low-achieving and 21 high-achieving fourth-year students and 10 low-achieving and 14 high-achieving fifth-year students diagnosed two clinical cases from written descriptions. Students were retested the following year. Analyses suggest that the increased expertise associated with advanced study that had been found in earlier studies are not so much induced by differences in factual knowledge, but rather by qualitative changes in the knowledge base, probably as a result of practical experience. Achievement level appears to have no effect on the structure measures investigated in this study. There is no indication that high and low achievers develop differently or at a different pace. Accuracy of diagnosis and explanations given by students tend to correlate with achievement level, but effects are less strong than those of experience. One table and two figures present study findings. (Contains 7 references.) (SLD)

Cognitive effects of the clerkship program in high and low achieving medical students[1]

Henny P.A. Boshuizen, Harry A.M. Hulsmans, & Gerard G.M. Essed

University of Limburg, Maastricht, NL

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Educational Research and Development
University of Limburg
PO Box 616
6200 MD Maastricht, Netherlands

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Introduction

Most medical curricula consist of a preclinical and a clinical period. In the preclinical period the emphasis is on knowledge and sometimes on skills acquisition as well, while in the clinical period students are supposed to learn to apply their knowledge and skills. These two learning activities are often strictly allocated to these two distinct periods. The idea behind this stringent division is twofold. One reason is an ethical one, i.e. that students first must have a sound body of knowledge and skills before they can be confronted with patients. The other reason has an epistemological background, i.e. that students first must have built up a complete and sound body of knowledge before they can learn to apply that knowledge in practical situations.

This dichotomy into different learning situations and activities result in an impetuous change in the students' tasks, responsibilities and experiences. During the preclinical period the chief activity has been learning from books, lectures and/or small group activities, depending on the curriculum structure (traditional or problem-based). Besides they also have had practicals giving them hands-on experience with lab procedures, and social, perceptual and psychomotor skills trainings preparing them for the requirements of medical practice. During the clinical rotations the role and the tasks of the student and the teacher changes completely. Now students have to interview and examine real patients all by themselves. They also have to show their manual skills such as making stitches, vaccinating a young child, or do some small surgery with real patients. Furthermore, they are expected to conform to professional standards. They are no longer allowed to behave like students. Instead, they must be recognizable as (future) doctors. And although the clinical staff is still responsible for diagnosis and treatment, students more than ever have the feeling that something is expected from them that really matters, not only to themselves, but also to the patients and to their supervisors. Not surprisingly many things change after a medical student has entered clerkship.

Evaluations of the effects of clinical rotations usually focus on the question whether the student has become a better doctor, i.e. whether the student has better attitudes than before and whether he or she has become more competent. Competence is often defined as the ability to apply the relevant knowledge and cognitive, perceptual, psychomotor and social skills in order to arrive at an appropriate diagnosis and plan of management and treatment. The assessment tools applied, such as OSCEs focus on the skills that are demonstrated in such cases.

The focus of our research is a different one. Our main interest concerns the cognitive processes that underlie this competence improvement. Earlier research has suggested that the development of medical expertise is not only associated with further knowledge and skills acquisition, but that a knowledge restructuring process termed 'knowledge encapsulation' and illness script formation plays a pivotal role in this process (see Boshuizen & Schmidt, 1992;

Schmidt & Boshuizen, 1993a). In our theory we assume that especially the practical application of biomedical knowledge, which is predominantly learned during the preclinical curriculum part, results in knowledge restructuring. This knowledge restructuring has been observed in several studies using different paradigms. In one study (Schmidt & Boshuizen, 1993b) it has been found that medical experts (experienced physicians) use less biomedical concepts in explaining the pathophysiological processes than underlie a patient's signs and symptoms. On the other hand, the same experts used more concepts that were identical or equivalent to the concepts used in a model explanation of the same case than medical students of various levels of training applied; contrary to the students they used hardly any concepts that are at a more detailed level than the model explanation. This finding was replicated by Van de Wiel, Boshuizen and Schmidt (1994), using four new cases. This finding was taken to indicate that biomedical knowledge restructures in such a way that detailed biomedical concepts encapsulate under 'higher level', clinically relevant concepts.

Furthermore, in a study in which a think-aloud method and a post hoc explanation task were combined (Boshuizen, 1989; Boshuizen & Schmidt, 1992), it was shown that fifth year students[2] by the end of their junior clerkship year and medical experts hardly applied any biomedical knowledge in clinical reasoning. On the other hand, fourth year students appeared to apply elaborate biomedical knowledge when trying to diagnose a case. These observations are in line with the findings by Schmidt and Boshuizen (1993b). Fifth year students instead tried to diagnose medical cases utilizing clinical knowledge, like experienced physicians. They seemed to have activated some illness scripts. However, the illness scripts that these fifth year students tried to apply, were incomplete and rather inflexible. Furthermore, the experts appeared to apply clinical or disease knowledge in clinical reasoning that integrated highly encapsulated biomedical knowledge (or compiled biomedical knowledge as it is called in earlier publications). This was not the case in the fifth year students whose biomedical and clinical knowledge seemed not to be integrated (Boshuizen, 1989; Boshuizen, Schmidt & Coughlin, 1988).

An explanation for this discontinuity in the restructuring of the knowledge base is suggested by research outcomes described by Boshuizen, Hobus, Custers and Schmidt (1992). In this study, subjects with different levels (4) of expertise, ranging from fourth year medical students to experienced family physicians were asked to describe prototypical patients having a specific disease or to describe its clinical picture. Subjects described 18 prototypes or clinical pictures. The results of this study suggested that the intermediate groups had elaborate knowledge about the separate components, but that these components were not yet very well integrated. This finding suggests that the development of illness scripts and encapsulation of biomedical knowledge is not the continuous and interlaced processes as was hypothesized before (see Schmidt & Boshuizen, 1993a).

[2] The undergraduate medical curriculum of the University of Limburg consists of a four years preclinical period and a clinical period of two years.

One of the problems with our research designs so far is that a cross sectional approach has been taken. Subjects are volunteers, but the different groups are recruited in different ways. Preclinical students often put their names on lists in which experimental subjects are asked to participate. This is a very clear form of self selection. Students participating in the clinical rotations or interns and experienced physicians are approached individually and asked to participate. Furthermore, the dangers of a cross-sectional design are, especially in a demanding domain like medicine, that the successive groups cannot be assumed to be one another's replications. I.e., the groups of experienced physicians (family physicians or internists) contained less females than the student groups, while they may also differ in term of intelligence, persistence, and so on. Yet, conclusions are made about the longitudinal development of medical expertise.

Such a incompatibility between the groups might have caused some of our findings. E.g., the finding that fourth year medical students applied detailed biomedical knowledge while fifth year students applied illness scripts (although not very flexible and detailed ones) might be caused by differences in amount and quality of the knowledge. This is suggested by the work by Lemieux and Bordage (1992), who found that outstanding students' clinical reasoning is based on deep, biomedical knowledge, while poor students' clinical reasoning is based on the application of defective knowledge or superficial knowledge consisting of unrelated lists of facts. Lemieux' and Bordage's findings suggest that the observed differences between fourth and fifth year students in our research outcomes might be due to individual differences in the two samples. The fourth year students group might have consisted of outstanding students applying deep, biomedical knowledge, whereas the fifth year group might have consisted of poor or mediocre students, applying superficial knowledge that might be taken for illness scripts application. Although we certainly had the impression that both groups consisted of rather good, well motivated students, no hard data are available to falsify this hypothesis.

This paper reports a follow-up study in which self-selection was minimized. Fourth and fifth year students were selected, based on a low or a high grade point average on the Maastricht progress test and were invited to participate in a one year follow-up study. By combining this follow-up and cross sectional approach a period of two years, covering the whole clinical period, can be reached. Using groups of high and low scoring subjects enables us to investigate the alternative explanation suggested by the Lemieux and Bordage findings. If the developmental path of weak students deviates from outstanding students', then high achievers might be distinguished from low achievers with respect to the quality of their diagnoses and the quality and organization of the knowledge applied in the case explanation.

Method

A combination of a cross-sectional and a follow-up methodology has been applied to investigate whether the knowledge development of weak and outstanding students is in the same way affected by the clerkships or whether they are differently influenced. Four groups of students were tested and re-tested after a year. A group of high and a group of low achieving fourth year students were tested by the end of the pre-clinical period, and one year later, halfway the clerkship period. Comparable groups of fifth year students have been tested halfway the clerkships and one year later by the end of it, just before or even shortly after graduation. Selection of high and low achievers was based on their test performance on the Maastricht progress test. A double blind procedure with respect to selection criterion has been applied. Furthermore, a reference group of a sample of experienced physicians (gynaecologists) has been included.

Students were asked to diagnose two clinical cases (presented on paper): an anemia case and a menstruation disorder case (see appendix 1). After diagnosing each case, the students were requested to explain the process that is underlying the patient's signs and symptoms. Analysis of expert performance provided us with an anchoring point. Two parallel cases, of equal complexity and from the same class of diseases, have been selected. Presentation order was balanced across subjects (see appendix 2).

Subjects and selection

The scores on two Maastricht progress tests, taken in September and December were used as a criterion. These scores were expressed as percentile scores based on the number of correct answers[3]. These percentile scores are calculated per year group. As a consequence, the fourth-year and the fifth-year student both scoring in the 100th percentile have different raw scores, e.g., 48% vs. 58% correct answers. Students with an mean percentile score ≥ 80 or ≤ 20 were invited to participate in this study.

The class of fourth-year students consisted of 167 students. Thirty of them had a mean percentile ≤ 20, 25 had a mean percentile score ≥ 80 on the two tests. (This difference might indicate that high scores are more persevering than low scores. Probably a low score motivates students to work harder, especially in the fourth year where there are less possibilities for compensation than in the fifth year.) These people were individually approached and urgently requested to participate. Despite this individual approach it was very difficult to include low achievers in the study. They were hard to contact, and it was still harder to convince them to participate. Even then the experimenters faced a great deal of no-shows. Nine of the low achievers and 21 of the high achievers participated. There were 126 fifth year students. Twenty-seven of them had a mean percentile score ≤ 20, 24 had a mean percentile ≥ 80 on the test. Of this group ten of the low achievers and fourteen of the high achievers participated. One year later, on the follow-up test these students were again approached. Except for three students, everyone could be reached. These numbers are summarized in Table 1.

[3] To prevent undesirable answering strategies student assessment is based on the number of correct answers decreased by the number of incorrect answers. Measures based on the number of correct answers are preferred for research, because these have better psychometric charateristics.

Table 1

Total number of fourth- and fifth-year students, number selected and number participating in the two measurements.

	total group	selected	participated; 1st measurement	participated; 2nd measurement
Fourth-year students	167	≤ 20 N = 30 ≥ 80 N = 25	≤ 20 N = 9 ≥ 80 N = 21	≤ 20 N = 9 ≥ 80 N = 20
Fifth-year students	126	≤ 20 N = 26 ≥ 80 N = 24	≤ 20 N = 10 ≥ 80 N = 14	≤ 20 N = 9 ≥ 80 N = 13

Analysis

Quality of the diagnoses and the quality and organization of the knowledge applied in the case explanation were determined, applying measures derived from Boshuizen and Schmidt (1992) ηd Schmidt and Boshuizen (1993b). These studies have shown that level of expertise is associated with (a) detail and precision of the diagnosis, and (b) has an inverted U-shaped relation with elaborateness of the explanation of the process underlying the patient's signs and symptoms: first an increase is observed, followed by a decrease in the clinical years. Furthermore, explanations of subjects at higher levels of expertise showed (c) a closer concurrence with a model explanation (explanation and model have an increasing number of concepts in common), (d) a decrease in the level of detail of the explanations, (e) an increase in the number of model concepts that are omitted in the subjects' explanations, and (f) a greater confinement of the subjects' explanation to the concepts applied in the model explanation (e.g., subjects restrict themselves to the explanation of relevant signs and symptoms, or do not give alternative explanations of the findings). An example of such a model explanation can be found in appendix 3.

Measures c through e are associated with knowledge encapsulation (clustering of detailed, biomedical concepts under higher order, often semi-clinical labels), while measure c, concurrence with a model also gives an indication of the quality of the knowledge applied. The last one, f, can be seen as a result of the increasing coherence of the internal representation a subject has built of a case, and is also an indication of the quality of the knowledge applied. The better the activated knowledge matches the case description (and the model) the more the case can be explained as a whole and the less local explanations for non-fitting items have to be constructed, hence less deviations from the model will be observed. This situation would occur when a subject has developed a sound knowledge base consisting of well differentiated illness scripts.

Data were analyzed applying level of experience (fourth-, fifth- and sixth-year students) and level of achievement (low, intermediate and high) as independent variables, with repeated measurement over cases. Three in stead of two achievement levels were compared: (1) Students who scored consistently high on the progress tests that were used as a selection criterion *and* on two successive progress tests one year later, (2) students who scored consistently low, and (3) students who regressed toward the mean (the intermediate group). The last group consisted of ten students: Two low-achieving and four high-achieving fourth-year students, and two low-achieving and two high-achieving fifth-year students.

Results and discussion

Analysis of (a) the quality of the diagnoses showed a positive linear effect of experience level ($F(2,96) = 3.159$; $p = .0469$): sixth year students had better diagnoses than fifth year students who had better diagnoses than fourth year students. Furthermore, there was a marked tendency that high achievers had better diagnoses than low achievers ($F(2,96) = 2.852$; $p = .0626$). The anemia cases turned out to be easier than the menstruation disorder cases, especially for fourth- and fifth-year students ($F(1,96) = 10.390$; $p = .0017$). Figure 1 shows that the performance of the high achieving sixth-year students comes close to the specialists' performance.

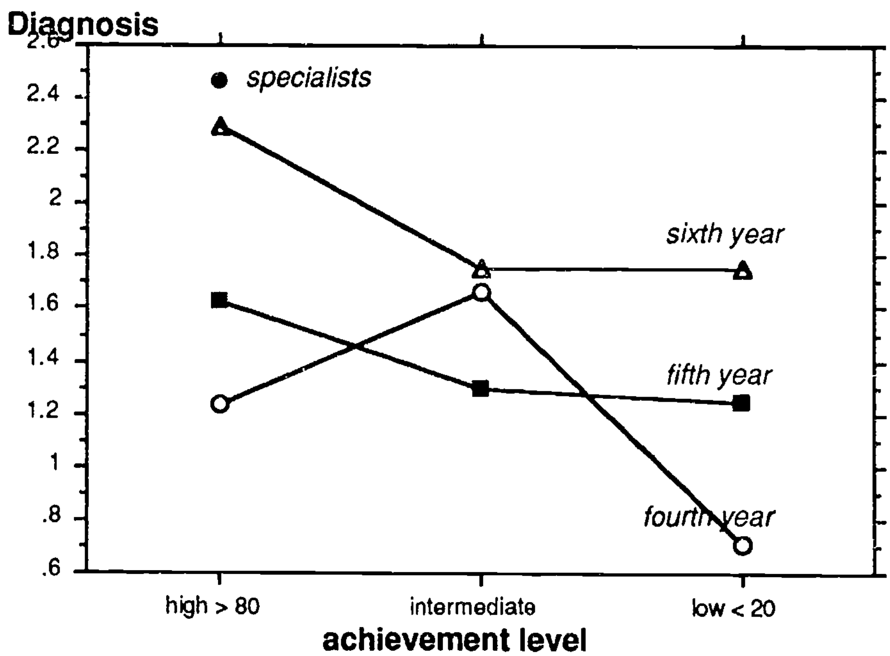

Figure 1. Diagnostic accuracy of subjects of different levels of achievement and experience.

(b) The elaborateness of the explanations of the process underlying the patient' signs and symptoms tended to decrease with increasing experience ($F(2,96) = 3.627$; $p = .0303$), coinciding with the second, negative slope of the inverted U-shaped relation reported in earlier studies (Schmidt & Boshuizen, 1993b). Means varied between 16.5 (sixth-year students) and 22.5 (fourth year students). The elaborateness of the explanations provided by the experts (mean = 15.5) could not be distinguished from the sixth year students'. Student-Newman-Keuls comparisons only revealed a significant difference between fourth and fifth year students (means 22.5 and 16.8 respectively). Achievement level had no effect ($F(2,96) = 1.395$; $p = .2527$). Case had a significant effect ($F(1, 96) = 4.995$; $p = .277$): The anemia case was more elaborately explained than the menstruation case.

The quality and structural aspects of these explanations, and hence of the knowledge applied in it, both varied with experience and achievement level, dependent on the measure observed. The present analyses suggest that the explanations of students with higher achievement levels tend to have (c) more concepts in common with the model explanation than the explanations made by students with lower achievement levels ($F(2,96) = 2.941$; $p = .0576$), while experience has not such effects ($F(2,96) = .217$; $p = .8056$). Figure 2 shows that again the high achieving, sixth-year students come closest to the specialists.

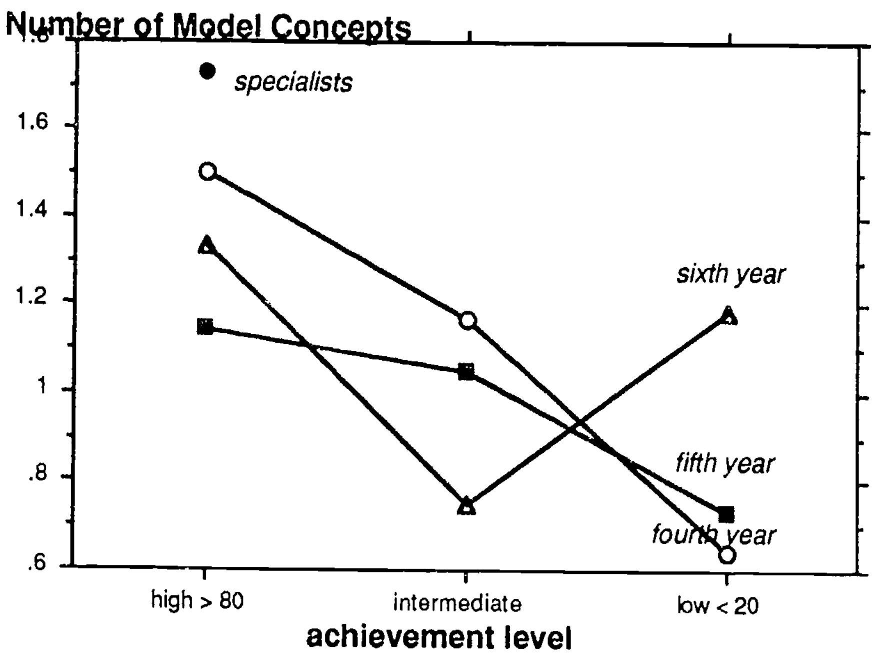

Figure 2. Number of model concepts in the explanations of subjects of different levels of experience and achievement

Furthermore, (d) the number of detailed concepts decreased with increasing experience levels ($F(2,96) = 3.451$; $p = .0357$), while achievement level had no effect ($F(2,96) = 1.179$; $p = .3120$). (e) The number of omitted model concepts in the explanations varied with experience level ($F(2,96) = 3.649$; $p = .0297$). However, this effect was not as expected: fifth year students omitted less concepts than the others, especially in the anemia case. Achievement level had no effect ($F(2,96) = 1.002$; $p = .3711$). Finally, (f) the explanations of more experienced students tended to be more confined to the canonical model. Their explanations contained less concepts that were in no way related to that model ($F(2,96) = 4.156$; $p = .0186$). Achievement level again had no effects ($F(2,96) = .439$; $p = .6458$). Table 1 summarizes these findings.

Table 2
Summary of effects of amount of experience and achievement level on six dependent variables

	effects of amount of experience	*effects of achievement level*
a. diagnosis	$p < .05$, increase	$.05 < p < .10$, increase
b. elaborateness	$p < .05$, decrease	$p > .10$
c. concepts identical to the model explanation	nil	$.05 < p < .10$, increase
d. detailed, biomedical concepts	$p < .05$, decrease	$p > .10$
e. omitted model concepts	$p < .05$, V-shaped	$p > .10$
f. loose concepts	$p < .05$, decrease	$p > .10$

These analyses suggest that, in general, the expertise effects found in earlier studies are not so much induced by differences in factual knowledge but rather by qualitative changes in the knowledge base, probably due to practical experience. The hypothesis that earlier observed differences between fourth- and fifth-year students in the application of detailed biomedical knowledge might be an effect of differences in achievement levels of the subjects participating in that study can be rejected: achievement level has no effect on the structure measures investigated in this study. There is no indication that high and low achievers develop differently, or at a different pace. This does not mean that achievement level does not play a role in clinical practice: both the accuracy of the diagnoses and explanations tend to correlate with it, but the effects are less strong than the experience effects.

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Appendix 1.

Example of a case applied

1. Female, 21 years old, no children
   Profession: secretary

2. Prior history: Menarche at age 13. Since that time irregular periods every 4 - 6 weeks

3. Prior history: The duration of the menstrual bleeding is variable.
   In case of pre-menstrual sensations it often takes about 5 days. Otherwise when bleeding starts unexpectedly, it can last longer, up till 10 days.

4. Prior history: Two amenorrheic periods of 4 months

5. Prior history: appendectomy due to appendicitis at age 16

6. Setting: She has made an appointment with her family physician a few days ago. Time of consultation: 16:30.
   Complaint: Since six months the patient's menstrual cycle has a duration of 8-10 weeks; she is somewhat concerned about it. She wonders whether that is normal at her age.

7. History: Over the last year the patient seldom had pre-menstrual sensations like a tense feeling in the breasts or an altered mood; most of the time the menstrual bleeding starts completely unexpectedly. If she has had pre-menstrual sensations the menstruation takes about 5 days; if unexpectedly bleedings vary between 2 and 10 days.

8. History: Breast development at age 10. Puberty at age 11. First sexual intercourse at age 19; presently she has a steady sexual relation with one partner.

9. History: Anticonception: condoms

10. Physical examination: Slightly increased facial hair grow; whiskers and a slight moustache. Some facial acne.

11. Physical examination: Adipous impression; weight 75 kg, length 1.65 m

12. Physical examination: BP 125/80 mmHg

13. Physical examination: Male pubic hair pattern, increased hair growth on the thighs

14. Physical examination: Mammae: Normal size and consistency

15. Physical examination: External genitals: no anomalies at labia majora and minora; no anomalies at the clitoris

16. Physical examination: Speculum: vagina no abnormal discharge, nulliparous portio with erythroplakia

17. Physical examination: Bimanual palpation: normal uterus mobile and anteverted. Both adnexa somewhat enlarged (estimated diameter 4 - 5 cm)

18. Lab: at cycle day +30: prolactin normal; LH increased; FSH normal; LH/FSH-ratio increased; 17-ß-estradiol slightly increased; androstenedione slightly increased; free T4 normal; pregnancy test negative

Appendix 2.

Presentation order of the four parallel cases at the first and second measurement

Time$_1$	*Time*$_1$ *plus 1 year*
anemia A, menstruation A	anemia B, menstruation B
anemia A, menstruation B	anemia B, menstruation A
anemia B, menstruation A	anemia A, menstruation B
anemia B, menstruation B	anemia A, menstruation A
menstruation A, anemia A	menstruation B, anemia B
menstruation B, anemia A	menstruation A, anemia B
menstruation A, anemia B	menstruation B, anemia A
menstruation B, anemia B	menstruation A, anemia A

Appendix 3.

Example of a model explanation.